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Methods for Tripling the Capacity of the National Air Transportation System

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Work to date

- Original Study
- Extension 1
  - ATM Technology & Demand/Capacity Sensitivity
    - 22/60 – 35/60 – 22/80 – 35/80
- Extension 2
  - Refined Calculation of 22% Runway Capacity Increase due to ATM Technology
- NS 260
  - Sensitivity Analysis
  - A detailed look at the System Description

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Purpose

- NASA Aeronautics Enterprise Goal
  - Triple throughput of NAS (RPMs) over 25 years
- Assist NASA Strategic Planning Office
  - How does such an air transportation system look
  - What are the technologies needed?
  - What investments are needed today?
  - Where should resources be placed?
  - What are the barriers to meeting the goal?
    - Technical, political, social, economic, financial, organizational

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Caveat

- Not a forecast
- Not a prediction
- Have not done a business case analysis

- Strictly a postulated construct
  - Aspects are plausible
  - A conceptual “strawman” for useful for
    - Examining a set of capacity enhancing concepts
    - What if analysis

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Original Study Summary

- Describes concepts for future NAS that achieves the 3X OAT 2022 Capacity Goal
  - Serve 97% of scheduled traffic via non-stop point-to-point routing
  - Increase runway capacity by 22%
  - Redistribute congested hub traffic to nearby uncongested hubs
  - Initiate and/or expand service to local/secondary airports
  - Introduce new vehicles into the NAS
    - Runway Independent Aircraft, STOL, Long-haul small passenger jets
- Requires
  - Aggressive technology research & development
    - Technology advances beyond incremental increases in today's air transportation system, especially in air traffic management
    - New vehicles
  - New and innovative operational concepts for
    - Air traffic management and control
    - Runway usage
    - Ground facilities, terminals, gates
    - Integration of new vehicles into the NAS
  - Cooperation and coordination between
    - NASA, FAA, Airlines and Airports

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Future Air Transportation System

- Requirements
  - Meet NASA's Capacity Program Goal
    - 3X 1997 throughput
  - Incorporate cargo demand
  - Incorporate general aviation demand
  - Incorporate greatly improved functionality in Air Traffic Management systems and vehicles
  - Support improved mobility

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Key System Attributes

- Move from Hub & Spoke system to a Point-to-Point system to meet demand
- Air Traffic Management Technology is able to
  - Increase VMC capacity
  - Increase IMC capacity up to VMC capacity
- Ground, enroute, and terminal capacity grows to match the increase in runway capacity

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System Description - Demand

- Passenger Traffic
  - 3x 1997 in terms of origin and destination domestic passenger trips
  - Tripled 1997 international operations
  - Domestic cargo operations
    - From 2% of passenger operations in 1994 to 5% of passenger operations in year 3X
  - 1997 general aviation operations tripled
    - Includes projected SATS growth

  - Resultant traffic schedule ignores current airline business strategy
    - Focuses on passenger preferences of point-to-point travel with a quality of service at least as good as today

Point-to-Point Schedule Creation

- Calculate daily demand by airport pair from the O-D data
- Demand divided into 4 markets
  - Short haul/long haul based on 500 mile split
  - Large demand/small demand based on 50 daily passengers
- 4 markets regressed against current schedule to get service frequency
- Calculate frequency of operation for each city pair

Market	Distance	Seats	Statute Miles	Intercept	R-Squared	Load Factors
large	long	0.006006942	-0.001271873	2.2303	0.94	0.7
large	short	0.006624361	-0.012321804	6.8956	0.73	0.6
small	long	0.023623303	-0.001423347	0.6961	0.77	0.6
small	short	0.037807886	-0.002793974	0.7272	0.53	0.5
	Daily Service = seats * x + statute miles * y + intercept					
	Rounded up to whole flight					
	No service where Daily service <= .499999					
	Data source is OAG					

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System Description – Airports

- Conduct detailed analysis of flight schedules and runway capacity at 102 busiest airports
  - These airports account for 96% of year 2000 scheduled air carrier enplanements
  - Assumes only approved new runways
  - Good-weather capacities
  - Daily capacity over 18 hours
  - Balanced departure and arrival capacities
  - Key assumption that partially drives results
    - If operated at 60% capacity, all but the worst peak periods can be handled with little congestion
      - » higher the fraction, the easier the solution
      - » examining 80% for sensitivity analysis
- Included an additional 650 airports as relievers to provide more direct and distributed flights

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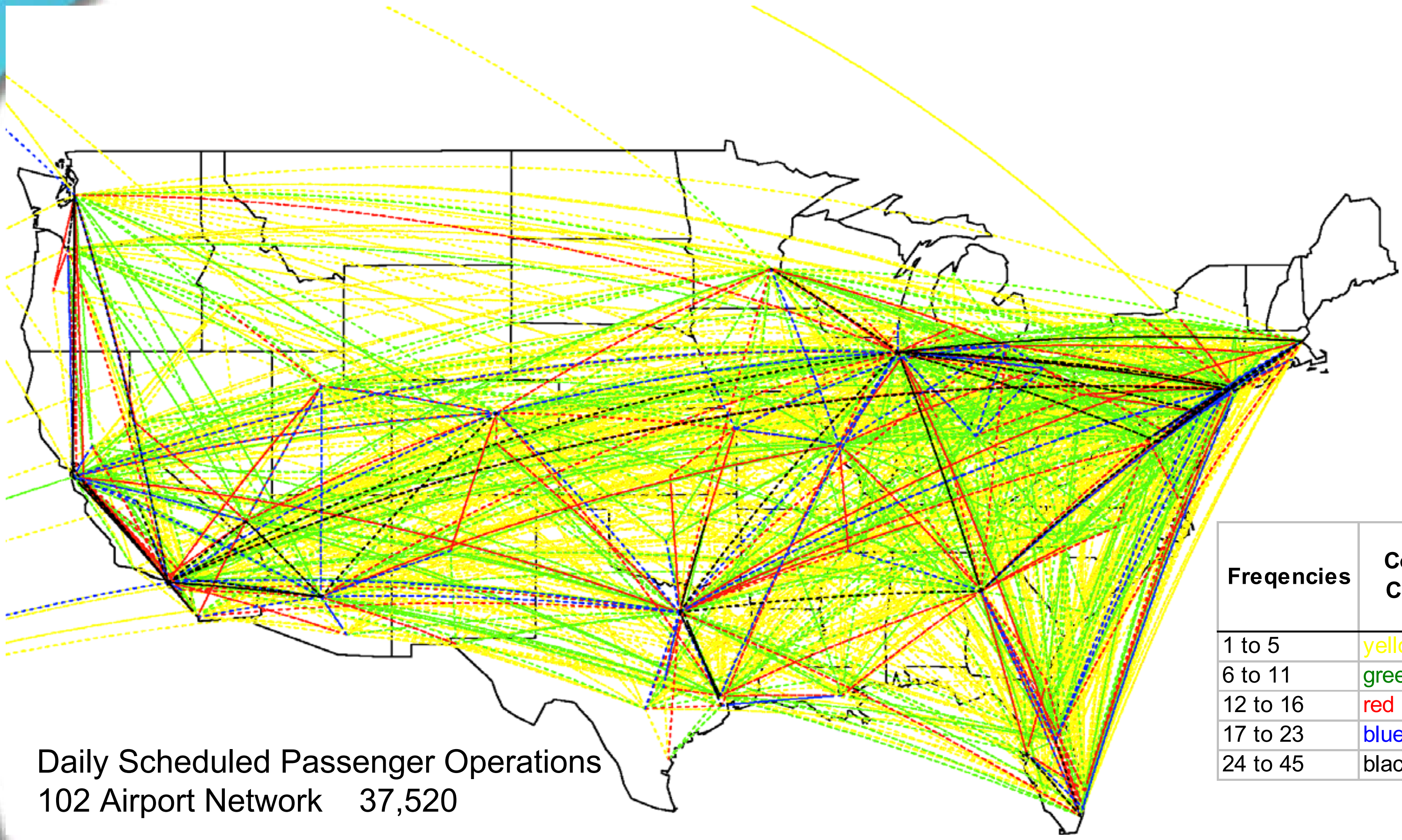
1997 OAG Traffic Pattern



Daily Scheduled Passenger Operations
102 Airport Network 37,520

Freqencies	Color Code
1 to 5	yellow
6 to 11	green
12 to 16	red
17 to 23	blue
24 to 45	black

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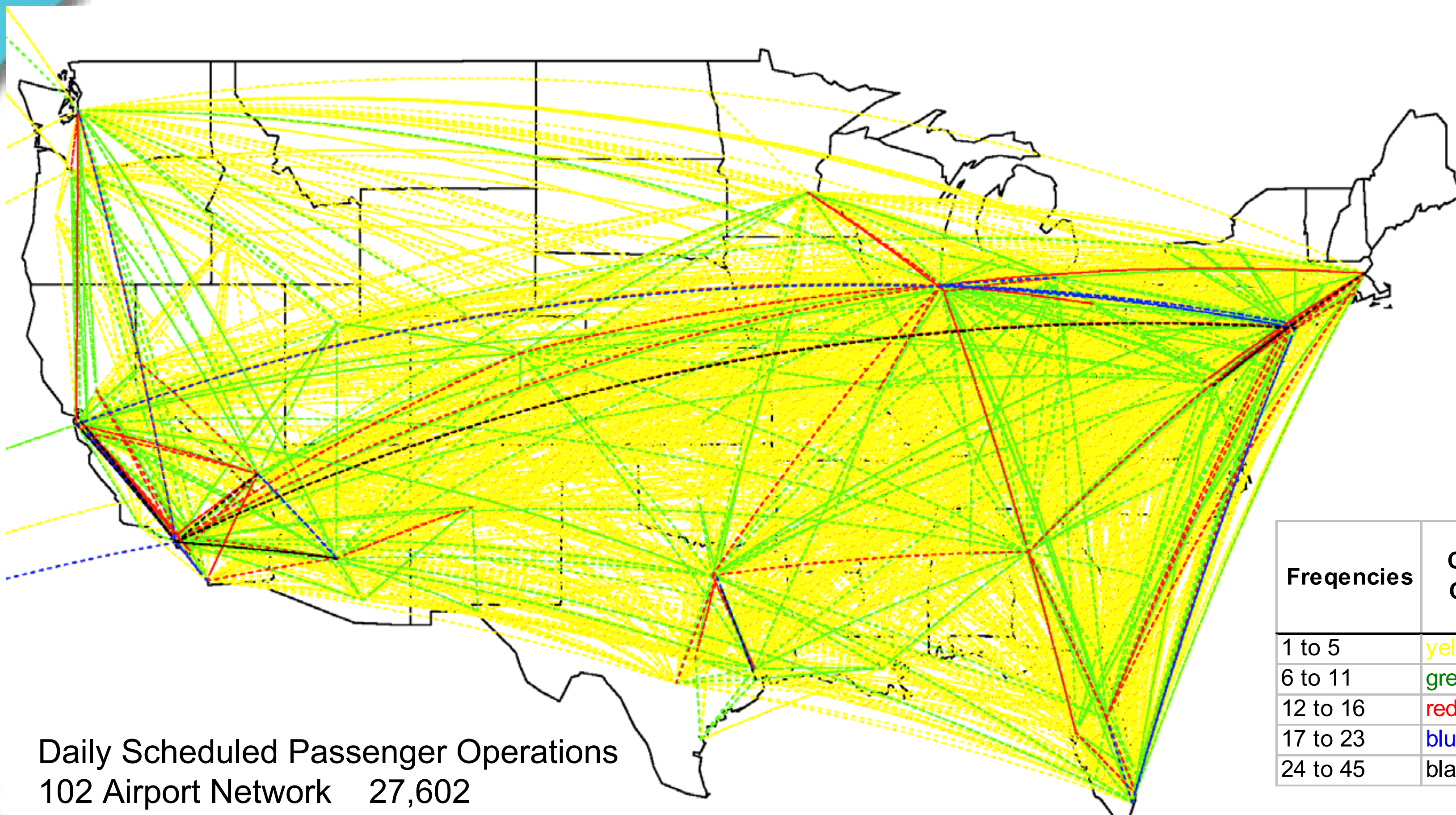
1997 Point-to-Point Schedule



Freqencies	Color Code
1 to 5	yellow
6 to 11	green
12 to 16	red
17 to 23	blue
24 to 45	black

Daily Scheduled Passenger Operations
102 Airport Network 27,602
But only flies 97% of the passengers

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2 Alternative Concepts

- True Point-to-Point
  - markets that do not justify traditional jet service are served by a set of alternative vehicles
  - all passengers receive point-to-point service

- Point-to-Point with Hub & Spoke
  - markets that do not justify traditional jet service are served by “pseudo” Hub and Spoke network
    - all airports are hubs in a Point-to-Point network

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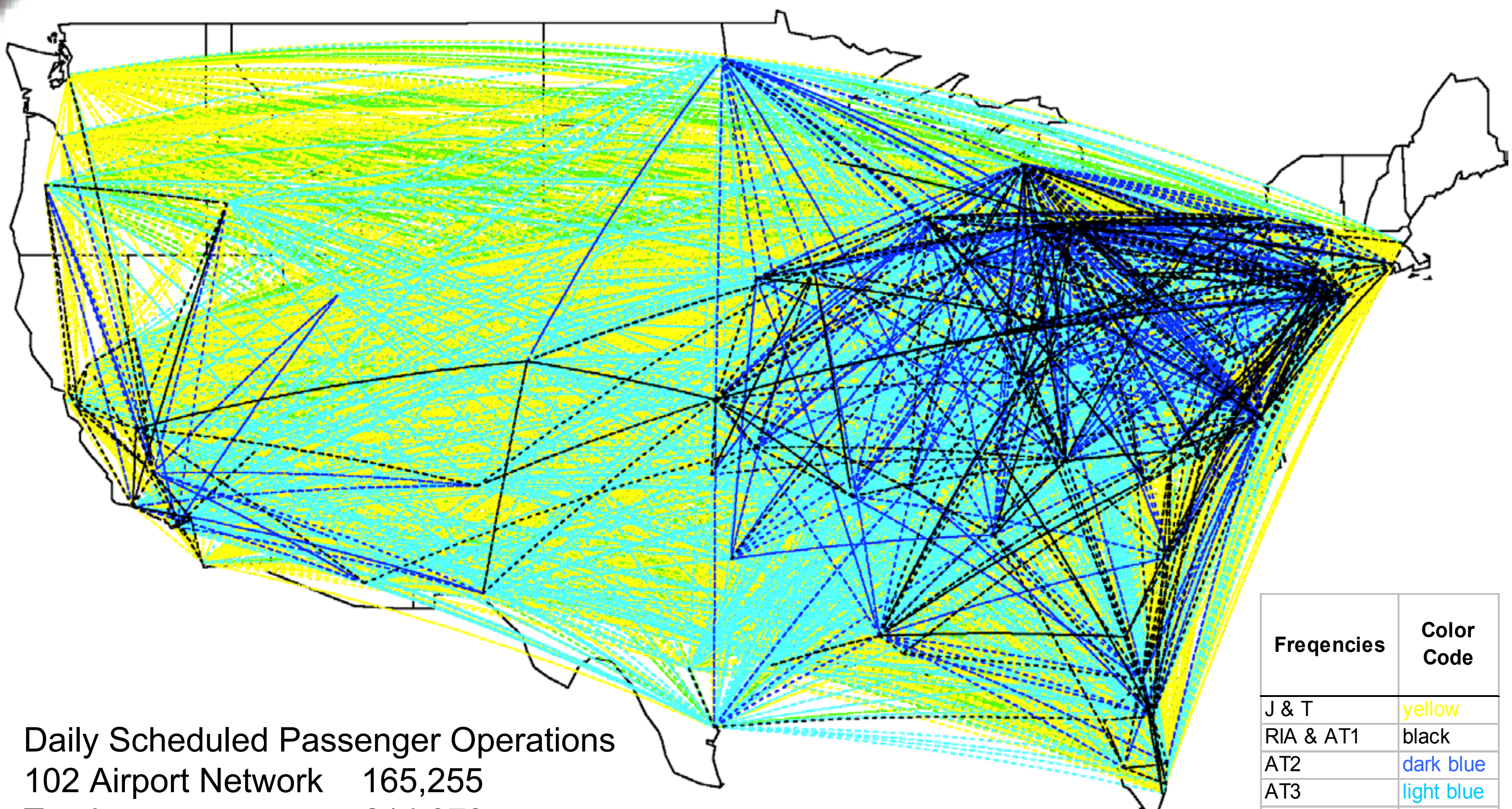
Point-to-Point Schedule
3x O-D

Minimum service frequency of 2 flights per day



Daily Scheduled Passenger Operations

102 Airport Network	165,255
Total	214,973

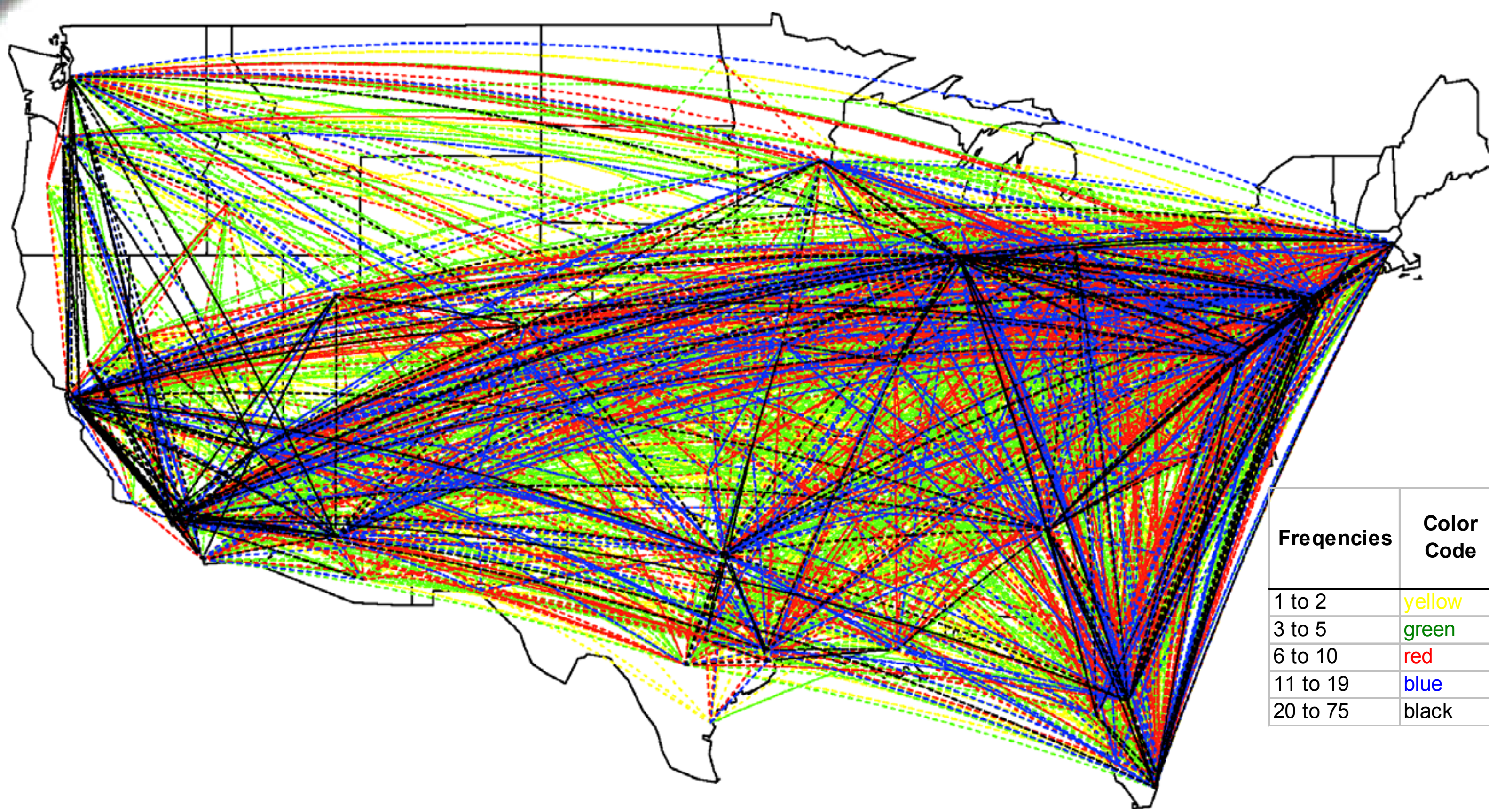
Freqencies	Color Code
J & T	yellow
RIA & AT1	black
AT2	dark blue
AT3	light blue
AT4	green

Point-to-Point Schedule

Supplemented with Hub & spoke

3x O-D

Minimum service frequency of 2 flights per day



Freqencies	Color Code
1 to 2	yellow
3 to 5	green
6 to 10	red
11 to 19	blue
20 to 75	black

Daily Scheduled Passenger Operations

102 Airport Network 76,612

Total 126,338

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3x Demand to Capacity Ratios

	Scheduled Air Carrier and Air Taxi		Demand/Capacity
Airport	**Maximum Daily Operations Capacity**	**Daily Operations Demand**	**Runway Ratio**
SAN	746	1304	1.75
LAX	2637	4608	1.75
SFO	1728	2840	1.64
LGA	1391	2216	1.59
EWR	1809	2668	1.47
LAS	1527	2214	1.45
JFK	1678	2404	1.43
BOS	1983	2578	1.30
DCA	1241	1546	1.25
SEA	1600	1962	1.23

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Solution Space

Adjust demand & capacity until target ratio reached

1. Apply capacity-enhancing effects of projected new Air Traffic Management technologies
2. Shift demand to nearby non-capacity-limited airports
3. Extend service to secondary airports
4. Insert Runway Independent Aircraft-type aircraft system to capture some demand
5. Use small aircraft (4 to 20 seats) to capture some demand
6. Use air taxi system to capture some demand

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Strategy 1 Air Traffic Management Technology

- 22% increase in capacity (both arrival and departure) during visual approach conditions
- Components
  - Improved data accuracy
    - No positional uncertainties
    - Standard deviations reduced by half
      - Approach and departure speeds
      - Wind speed
  - Communications delay and standard deviations virtually eliminated
  - Arrival runway occupancy time reduced to 38 seconds and its standard deviation reduced by half
  - Taxi delays reduced proportionally to runway capacity increase
  - Input stream gaps eliminated

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Strategy 2
Demand Shifting/Regionalized Airports

- Major airports within 50 miles of each other "share" runway capacity
- Demand from congested airports is moved to uncongested airports

airport	airport	change in demand	new scheduled operations	% of capacity	prior % of capacity
SFO	SJC, OAK	**-551**	**2320**	**110%**	**136%**
SJC	**SFO**	314	1331	60%	46%
OAK	**SFO**	237	1101	60%	47%
LGA	ISP	**-67**	**2165**	**128%**	**132%**
ISP	**LGA**	67	231	60%	43%
BOS	PVD	**-271**	**2321**	**96%**	**132%**
PVD	**BOS**	271	777	60%	39%

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Strategy 3
Secondary Airports

- Shift flights to secondary airports
  - But not to airports classified as GA
    - Non primary commercial service, commercial service reliever and reliever airports
  - Within 75 miles of a major 102 airport
- Methodology
  - For each airport, triple current demand, and use excess capacity
  - But
    - Many local/regional airports have no excess capacity
    - Availability varies by region
      - Many in the north east corridor
        - » Raises a set of non-technical barriers
    - Long runways in short supply
      - Necessitates a STOL vehicle, and/or
      - Or restriction to small passenger aircraft

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Strategy 4
Runway Independent Aircraft

- RIA concept is interchangeable with secondary airport concept
  - Issue is one of costs, monetary and non-monetary; as well as who bears those costs
- Use RIA at congested airport
  - RIA can operate in STOL mode at a non-congested airport or non-congested secondary airport
  - RIA can operate on stub runways at major airports (if available) or < 5,000 ft. runways at secondary airports
  - RIA might have to operate in vertical mode at some congested airports
  - Only examined 1 bank of RIA flights
    - 15 arrivals and 15 departures per hour, 18 hour days
    - 324 RIA operations per day
      - (15+15) *18 * .6

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3x Demand to Capacity Ratios

with strategies implemented

	Scheduled Air Carrier and Air Taxi		Demand/Capacity
Airport	**Maximum Daily Operations Capacity**	**Daily Operations Demand**	**Runway Ratio**
SAN	911	589	0.65
LAX	3217	3124	0.97
SFO	2109	1265	0.60
LGA	1698	1019	0.60
EWR	2208	1325	0.60
LAS	1864	1318	0.71
JFK	2048	1229	0.60
BOS	2420	1452	0.60
DCA	1515	909	0.60
SEA	1953	1252	0.64

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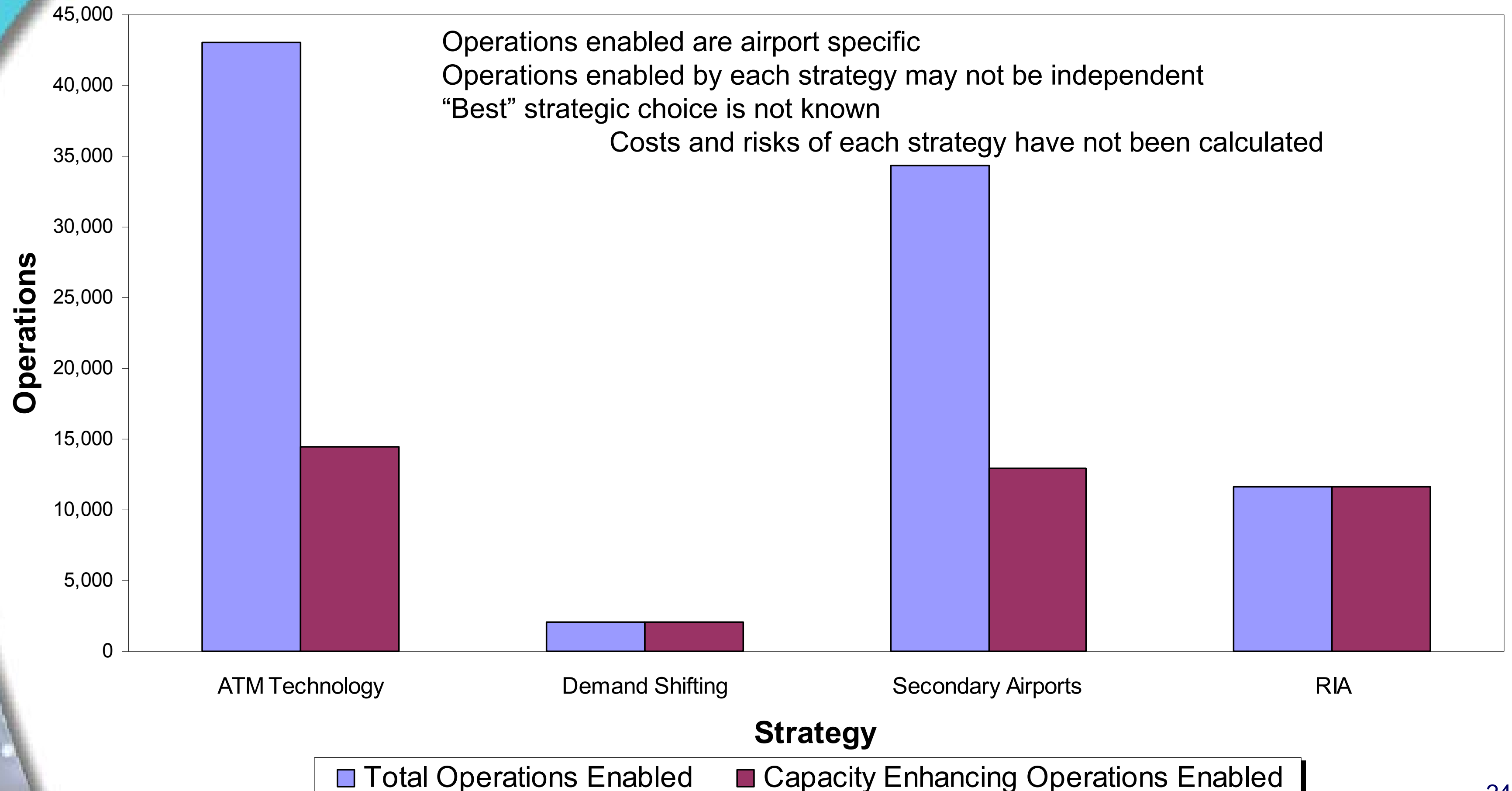
Strategies not examined

- RIA
  - 3rd bank of flights
  - Tightening arrival/departure rates
- Use of military airports
- Use of GA airports
- Runway allocations
  - Distance flown
  - Load factor
  - Number of passengers
- Removal of GA traffic from particular hubs
- Expanding 75 miles to 100 miles

Strategies Summary



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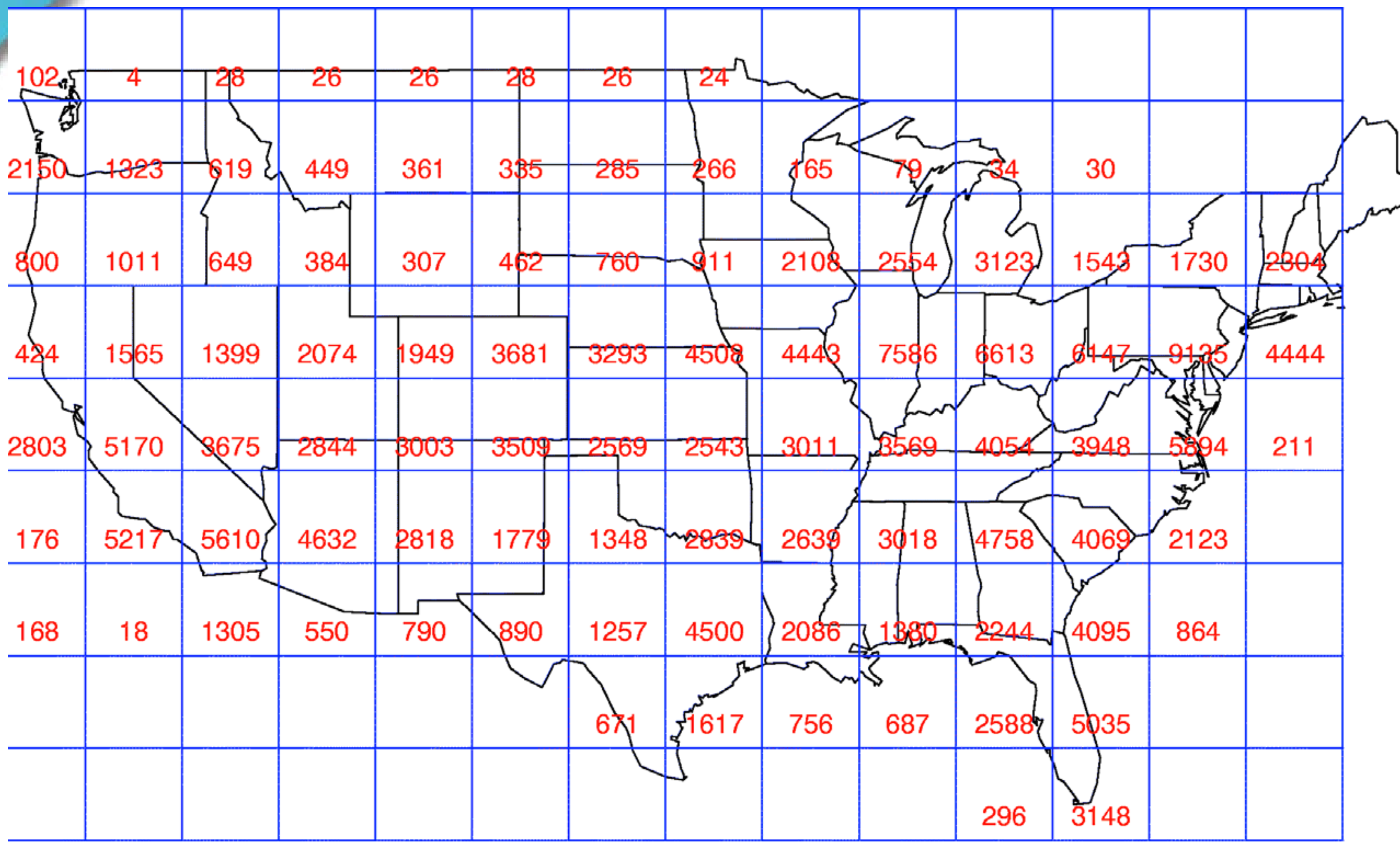
Daily Arrivals to Sectors
3x
102 airport network only



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Unresolved Issues

- Identify potential barriers
  - Follow on work?
- Evaluate economic feasibility of the Point-to-Point system
  - 25% P-to-P?, 50% P-to-P?, 75% P-to-P?
- List required technology development
- Complete airborne system vs. enhanced ground-based approach?

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Technology Development Issues

- Future System requires:
  - Airport capacity increases under all weather conditions
  - Air Traffic Management technologies to handle higher workloads and allocations
  - Ability to manage more complex traffic flows
    - Higher volume of traffic
    - Flow to more airports within a geographic region
    - Integration of new vehicle types into flows
  - New Vehicles
    - Runway Independent Aircraft
    - Air Taxis (8 to 20 passengers)
    - Short Take-off and Landing (<5000 ft) aircraft

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Extension 1

- What if the 22% estimate of ATM Technology is low
  - 35% represents an alternative scenario
- 60% Demand/Capacity is a function of the current air transportation system
  - Combination of
    - Hub and Spoke
    - Existing ATM Technologies
    - Existing Aircraft
    - Current Operational Procedures
    - Current Scheduling Practices
- Ratio before large delays may be higher in the future
    - 80% represents an alternative scenario

Case Summary

	Strategy 0 target ratio under	over	Strategy 1 target ratio cleared	under	over	affect	Strategy 2 target ratio cleared	under	over	affect	Strategy 3 target ratio cleared	under	over	affect
baseline 22/60	11	91	31	42	60	91	5	47	55	31	37	84	18	48
NAS Dynamics 22/80	53	49	25	78	24	49	7	85	17	26	14	99	3	16
ATM Tech 35/60	11	91	45	56	46	91	11	67	35	32	23	90	12	16
Optimistic 35/80	53	49	36	89	13	49	4	93	9	7	8	101	1	9

	Strategy 4a target ratio cleared	under	over	affect	Strategy 4b target ratio cleared	under	over	affect	Remaining Problem Airports
baseline 22/60	8	92	10	18	6	98	4	10	4
NAS Dynamics 22/80	2	101	1	3	0	101	1	1	1
ATM Tech 35/60	6	96	6	12	5	101	1	6	1
Optimistic 35/80	1	102	0	1	0	102	0	0	0

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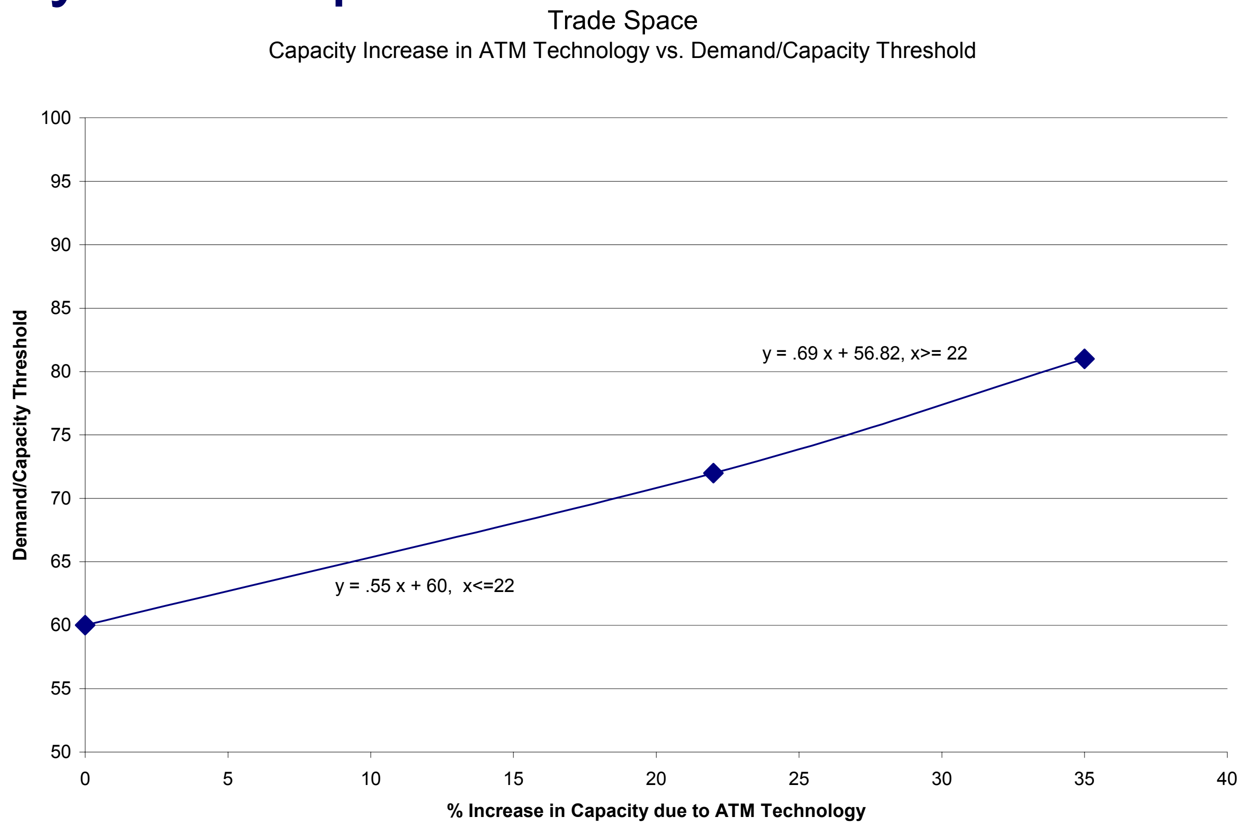
ATM Technology vs. System Dynamic

- Similar effects of explicit addition of ATM Technology and the raising the “System Dynamic” parameter



ATM Technology vs. System Dynamic

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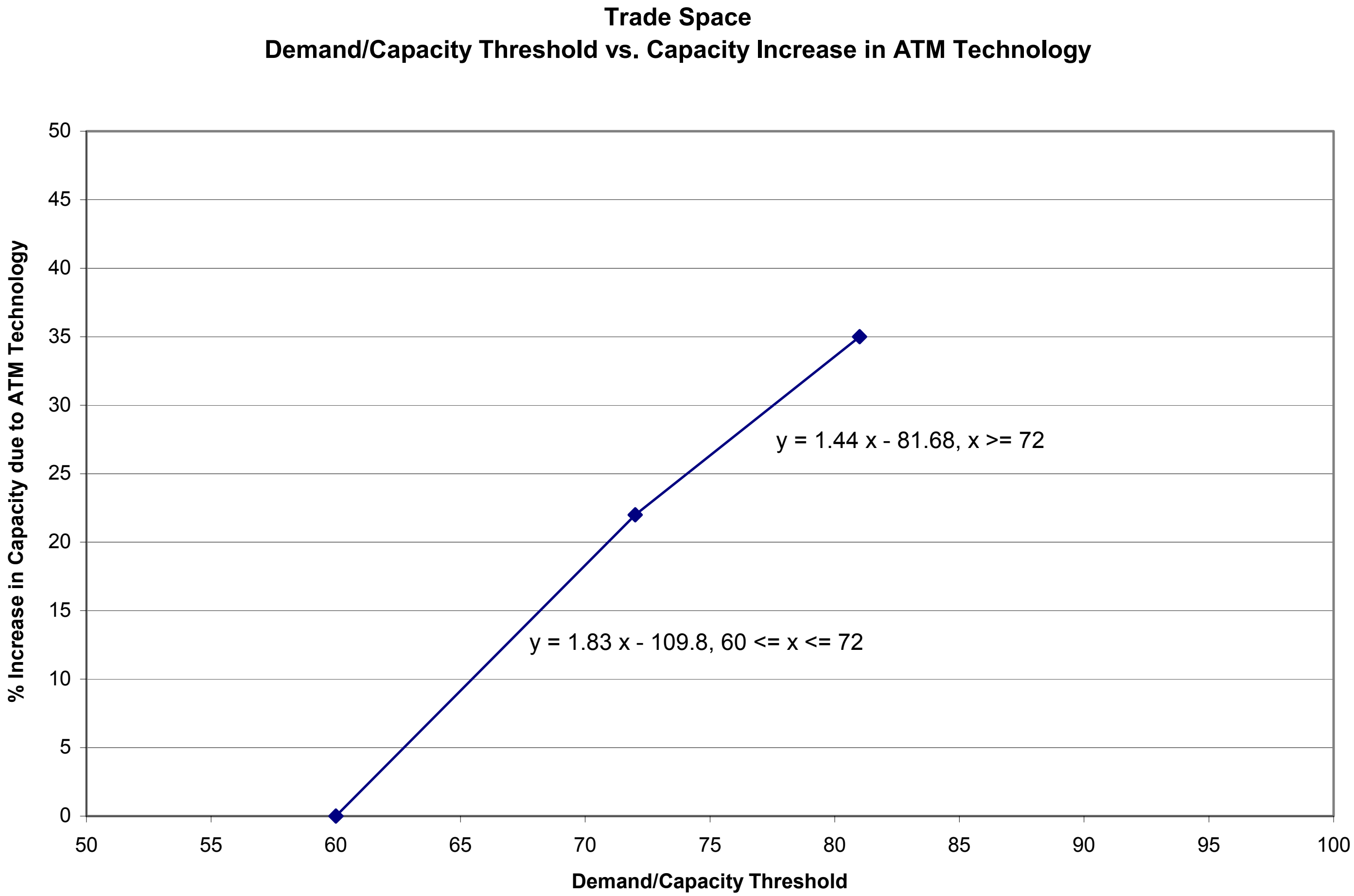
- Is one easier, cheaper to modify?



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Common Airport Analysis

- There are a set airports that are affected similarly by the differing strategies
- Similar salient airport characteristics?
- Do these define test airports for further analysis of the specific concepts?

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Common Airport Analysis – Demand Shifting

- 4 common airports for all 4 cases
  - LAX, DCA, SFO, and BOS
- 1 common airport for the 2 lower ATM Technology cases
  - MSN
- 8 common airports for the 2 lower System Dynamics cases
  - MSN, COS, BWI, DAL, SWF, BTR, FNT, and RDU

Implications

- Under a specific set of demand, capacity and ATM technology conditions,
  - There is an excess of supply of capacity that can be exploited and efficiently used
  - Since this capacity already exists, the main cost is “transference” of the demand to where the physical capacity is located

Common Airport Analysis – Secondary Airports

- 9 common airports for all 4 cases
  - LAX, LGA, EWR, JFK, LAS, SEA, ORD, PHL, and SAN
- 6 common airports for the 2 lower ATM technology cases
  - MIA, FLL, SAT, DAB, MSP, and HNL
- 11 common airports for the 2 lower system dynamic cases
  - FLL, SAT, HPN, PBI, SLC, TUS, LAX, LAS, SNA, PHX, and MLB,

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Implications

- Demand/capacity imbalance of these airports is significantly beyond the ability of aggressive ATM technology, and localized demand shifting.
- Require approaches beyond getting more use of the current airport infrastructure
- The significance is that, on a regional basis, major airports that “share” secondary airports may have a common ground for reallocating demand to those secondary airports.
  - One secondary airport may be able to service/siphon demand from 2 or more larger nearby airports.
  - This combined level of demand may be enough to justify new service or a new level of service at these secondary airports.

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Common Airport Analysis - RIA

- SAN is common to all 4 cases
- 2 low ATM Technology cases & 2 low System Dynamic cases both require 2 banks of flights
- MLB is the common airport in the 2 low ATM Technology cases
- 11 common airports in the 2 lower System Dynamic cases

Implications

- The RIA option represents a solution strategy for the most problem airports
- The airports requiring this strategy represent those with the most acute demand/capacity imbalance.
- Its use represents the combination of concentrated demand with relatively little local and regional availability of other airports overcoming the capacity increases of ATM technology improvements

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Results

- Obviates the need for some technology
- 80% ratio results in 42 less problem airports
  - Need less of the subsequent strategies
  - In conjunction with ATM Technology
    - Can avoid RIA or Secondary Airport usage in some markets
- Strategic choice will be important when costs of technology is factored in
  - Can technology or other systemic changes be cost effectively driven to the 35% or 80% levels?
- Common airports may represent similar intersections of demand, capacity, and regional characteristics, which are affected by specific strategies

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Extension 2

- Perform a finer/more detailed calculation of the 22% increase in runway capacity
- Initial calculation based on additional technology enabled operations at LAX, BOS, JFK, SFO
- Operations-weighted result was 22.78% and that was extended to 22% at all 102 airports

Results

- Original 22% estimate is high
- Refined calculation yields 14% NAS wide
- Refined calculation yields 17% at
  - LAX (15%), SFO (16%), EWR (14%), ORD (20%), LGA (16%)
- Depending upon the specific airport the exact point chosen on the departure/arrival curve
  - Resultant improvement ranges from 3% to 30%

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NS 260

- Started as incorporating Mobility Goal into the System Description that meets the Capacity Goal
- Change of Mobility Goal changed study
- Focusing on Sensitivity Analysis and Decomposing the 3x System Description
  - Characterize 3x System Description in terms that make it comparable to any other current or future System Description
  - Parameters include descriptions of demand, capacity, fleet sizes and mixes, robustness, network measures

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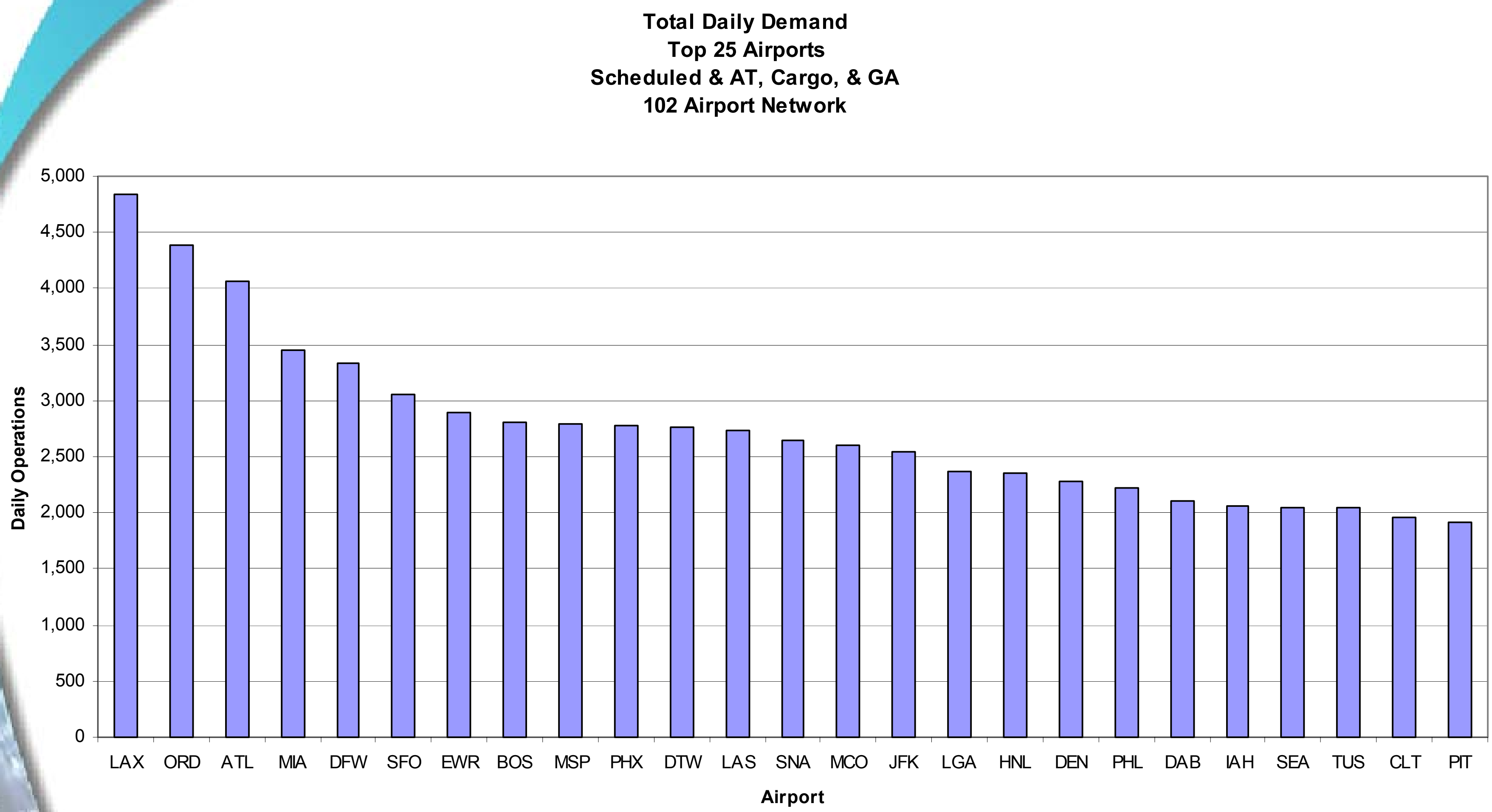
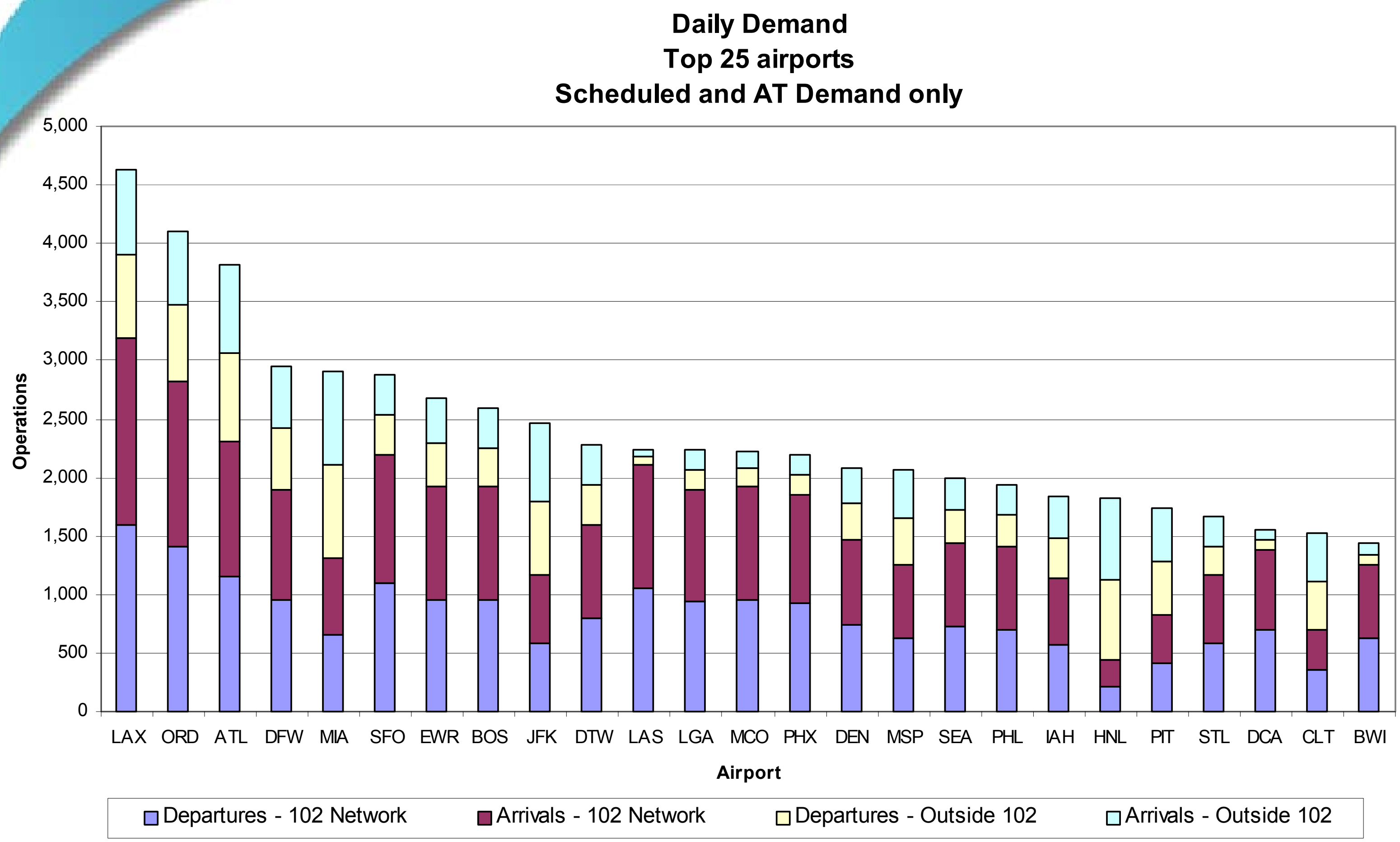
Total Daily Demand



Daily Demand Components



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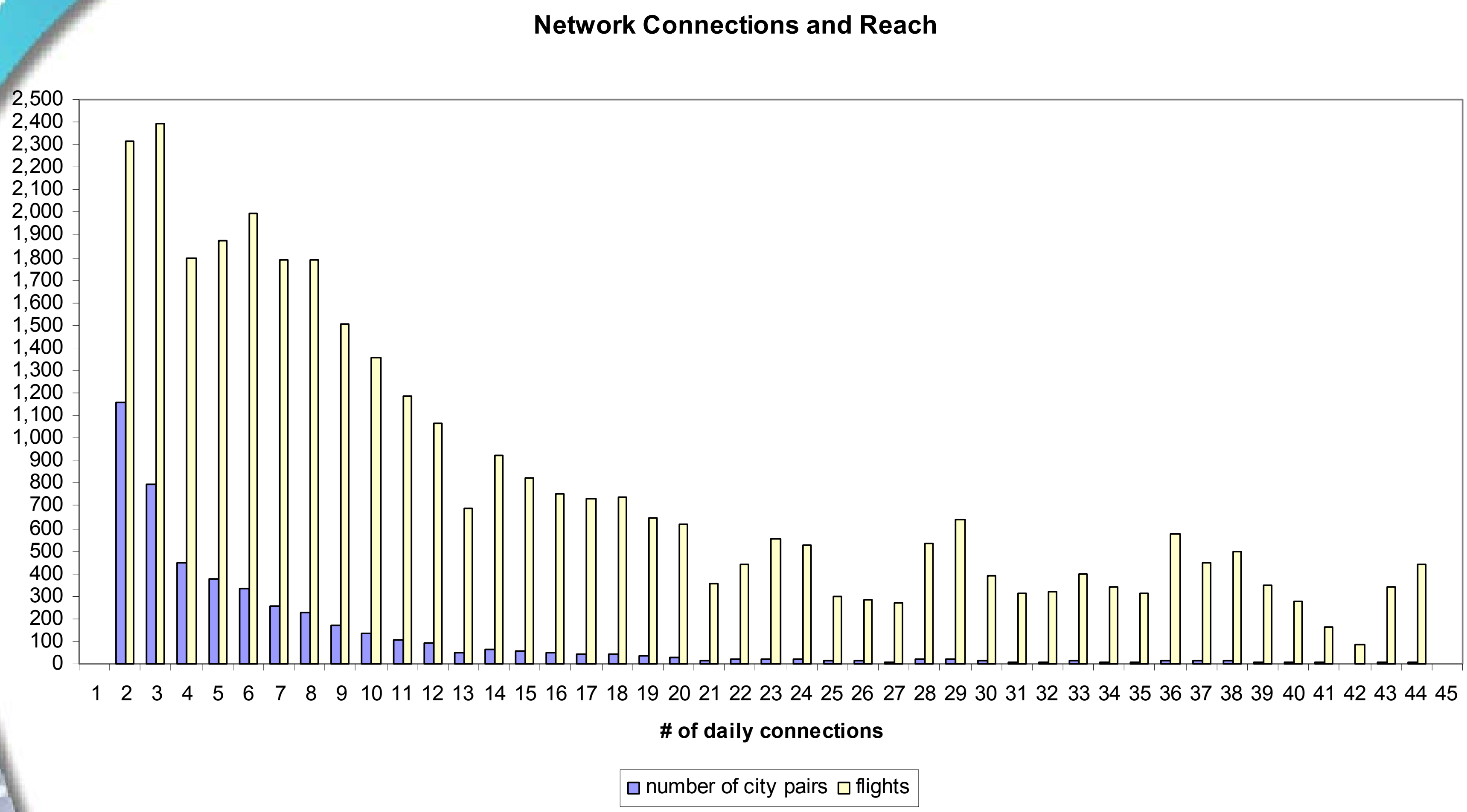
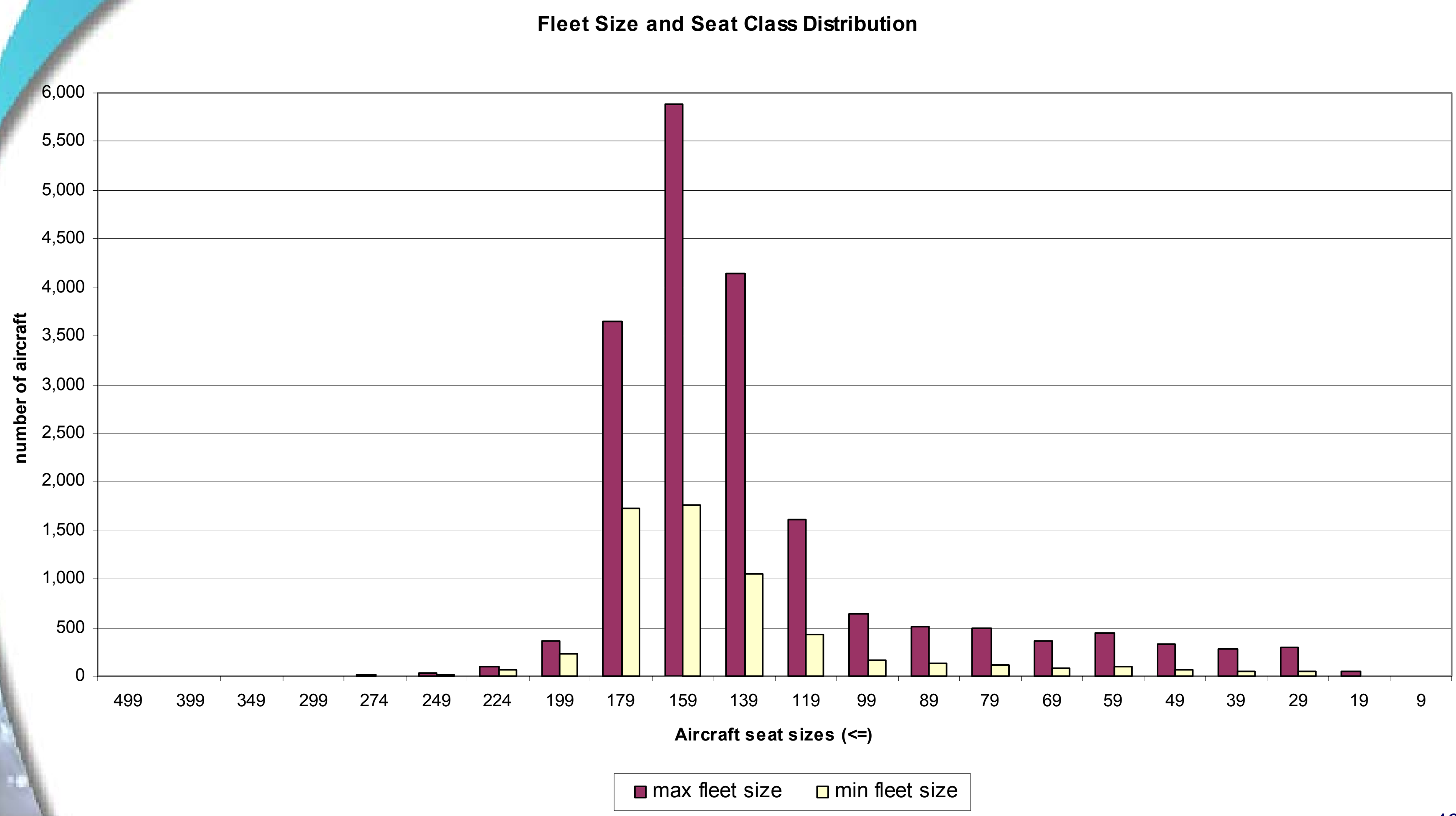
Network Connections and Reach



Fleet Size and Mix



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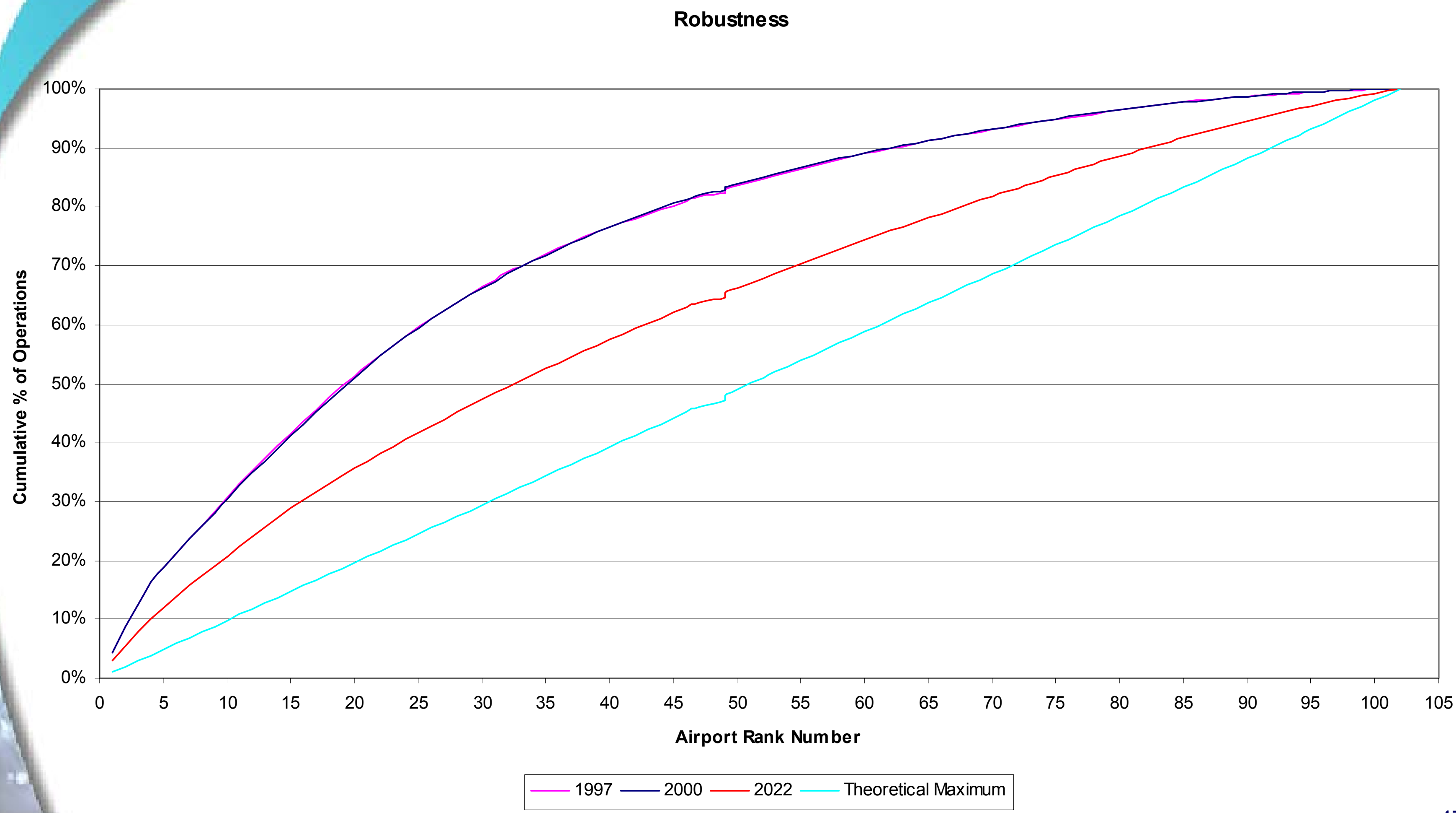
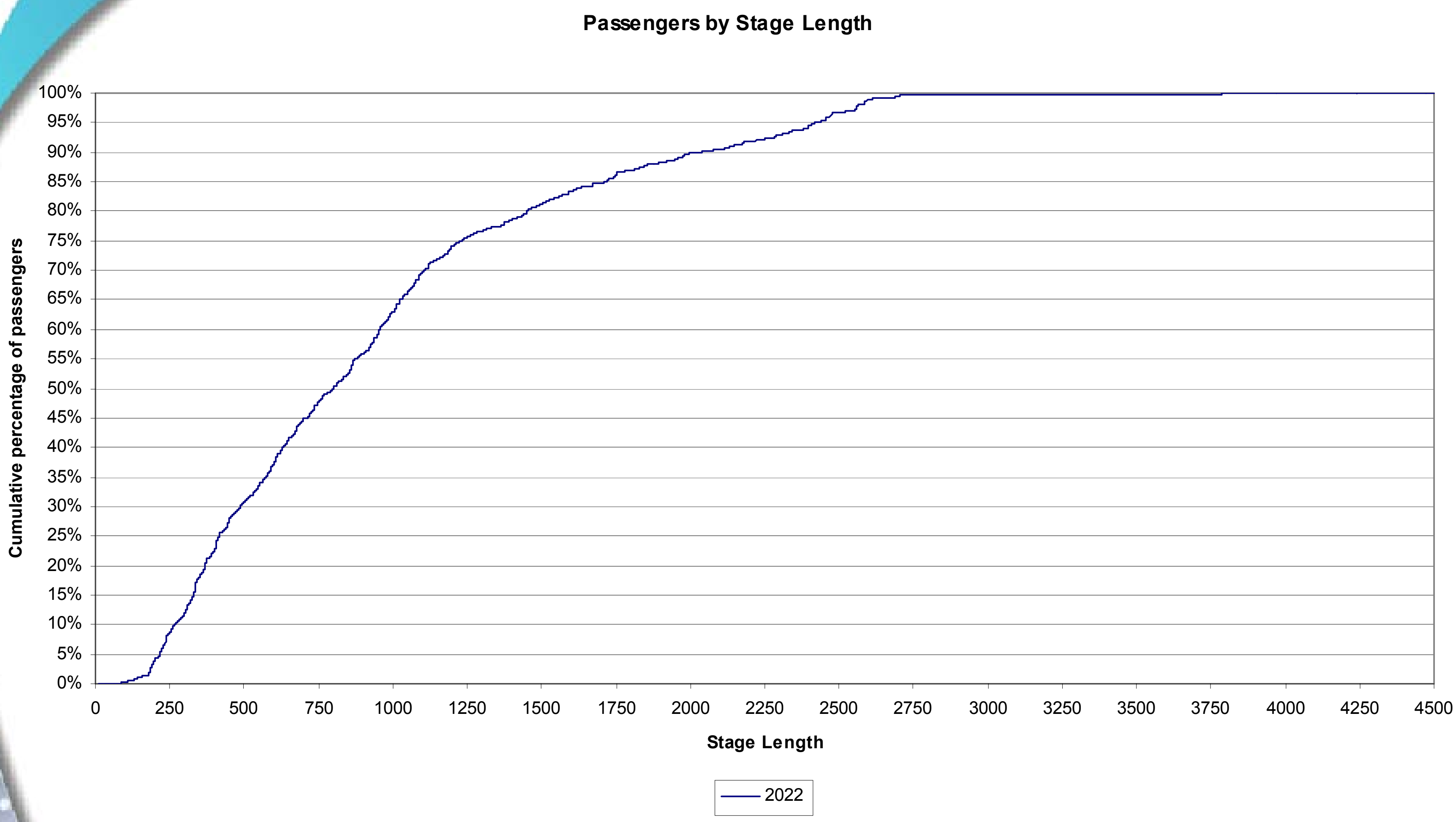
Robustness- Network Distribution



Passengers by Stage Length



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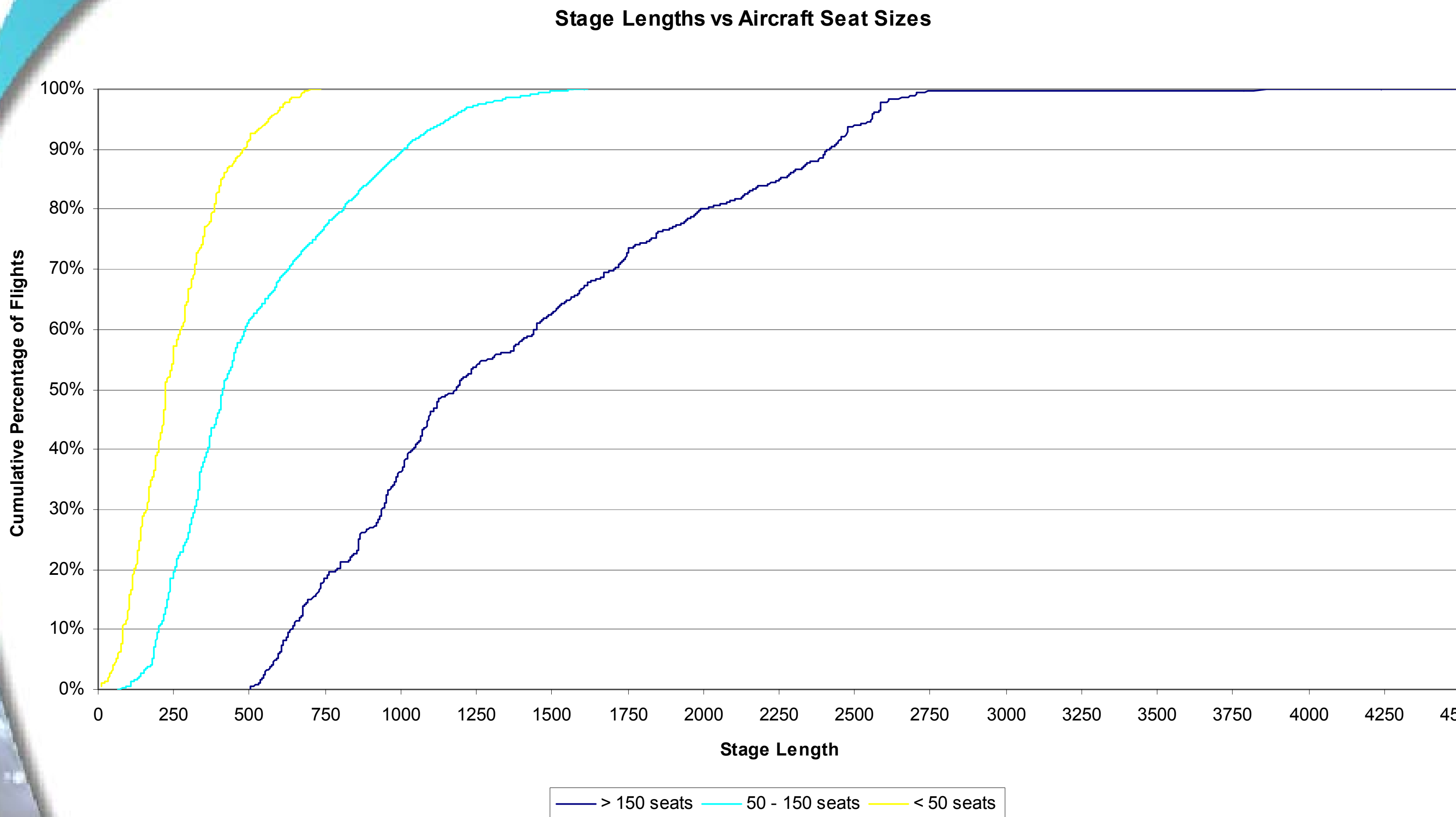
Stage Length vs. Aircraft Seat Size



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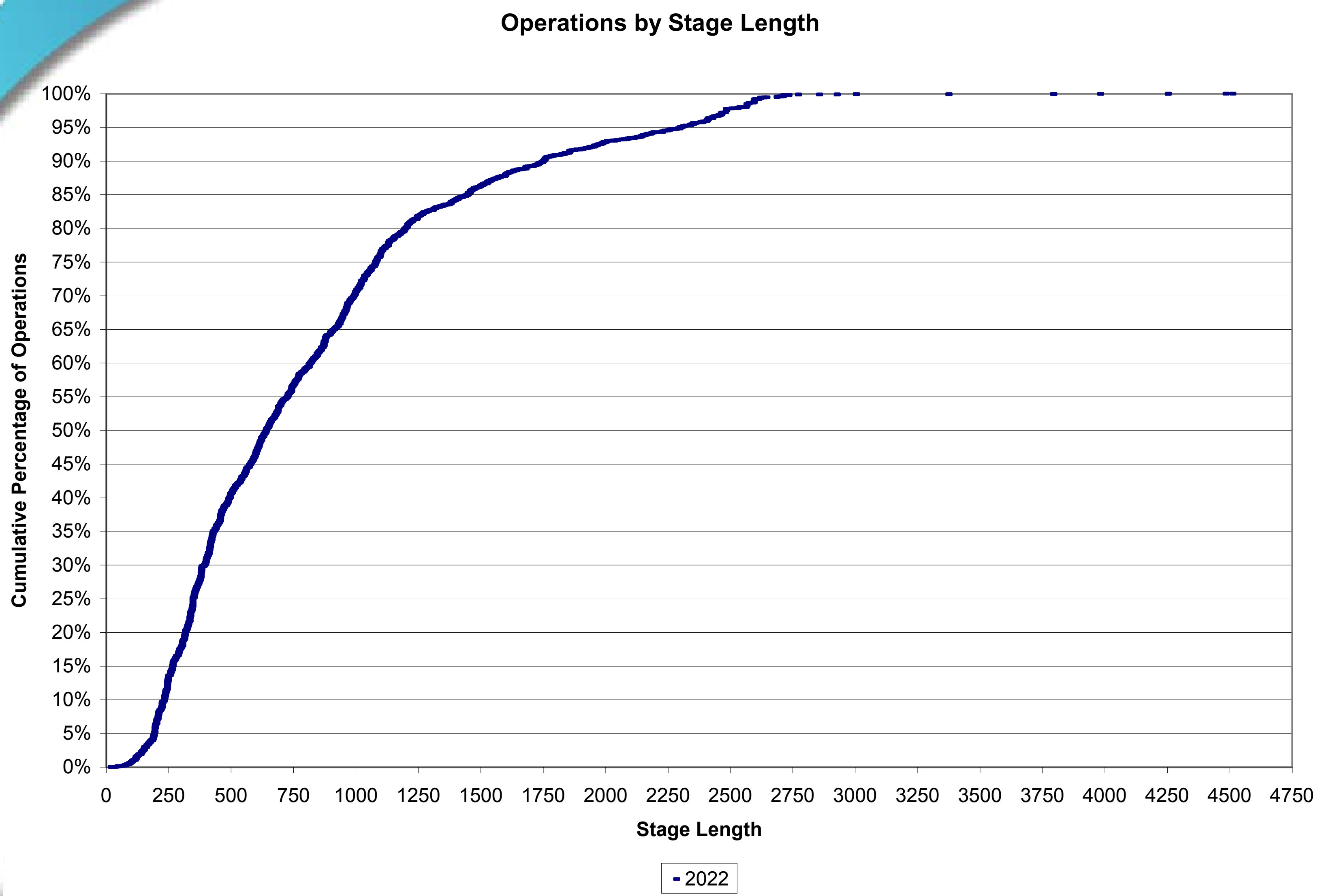
Operations by Stage Length



Service Frequency

- Critical competitive factor for Hub & Spoke
  - Does frequency of service compensate for extra time due to hubbing?
- Is it as Service Frequency as critical in Point-to-Point system?
  - No hubbing time losses for most markets
  - Implicit hubbing option is available by choice
  - Current schedule has some high service frequency flights
- What happens as service frequency is limited
  - Max 4 flights per hour – 15 minute intervals
  - 20 minute intervals
  - 30 minute intervals
  - 1 hour intervals

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Effects

- Operations are reduced
- Average aircraft sizes are increased
  - Viable fleet of 500 passenger aircraft
- Fleet sizes decreased

- Implications
  - Service of frequency rules can be beneficial
    - Used to control operations
      - May be some cost implications for the airlines
      - May be less stress via less operations on the ATM system